

PROJECT PROFILE

TITLE:

Development of a Land Use Mapping and Monitoring Protocol for the High Plains Region: A Multitemporal Remote Sensing Application

NASA NAGW-3810.

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DESCRIPTION:

(Description of project written for outside audience i.e., reader who is not intimately familiar with the technology, science, applications and techniques)

Background:

The importance of studies like this NASA project are outlined in the statement by Vice President Al Gore.

"In FY 93, the Federal government will invest in research to better understand global warming, ozone depletion, and other phenomena important to local, regional and global environments. This research is essential if we are to fully assess the damage mankind is doing to our planet and take effective action to address it. Vital research on local and regional environmental problems will also be strongly supported at ... NASA, and other agencies ... " (President Clinton and Vice President Gore, *Technology for America's Economic Growth, A New Direction to Build Economic Strength*, February 22, 1993.)

It is an irony that nearly 25 years after the launch of Landsat, there are still few detailed (1:24,000 scale) maps of land use and land cover for the U.S. In fact, the only nation-wide land cover maps available are rendered at 1:250,000 scale and they are over 25 years old. Our experience with these data has also shown their accuracy to be highly questionable. Yet, many research and land management objectives rely heavily on current land use and land cover information. The reason such information is lacking is that no cost effective method for developing detailed land cover maps has been developed. Earlier studies by the investigators of this project showed that automated classification approaches that use single-date Landsat imagery could be used to map very general land cover types (i.e., urban, agriculture, grasslands, forest lands, water, etc.). Without costly and time consuming human input, however, the single-date approach could distinguish between grasslands and croplands only 55% to 60% of the time in many areas of Kansas. As a result of earlier basic research findings, it was hypothesized that much greater land cover classification accuracy could be achieved using multiple-date (multitemporal) Landsat Thematic Mapper (TM) data along with a hybrid (combination of supervised and unsupervised) classification approach.

Project Purpose:

The purpose of this project was to develop a practical protocol that employs multitemporal remotely sensed imagery, integrated with environmental parameters to model and monitor agricultural and natural resources in the High Plains Region of the United States. The value of this project would be extended throughout the region via workshops targeted at carefully selected audiences and designed to transfer remote sensing technology and the methods and applications developed.

Implementation of such a protocol using remotely sensed satellite imagery is critical for addressing many issues of regional importance, including:

1. Prediction of rural land use/land cover (LULC) categories within a region;
2. Use of rural LULC maps for successive years to monitor change;
3. Crop types derived from LULC maps as important inputs to water consumption models;
4. Early prediction of crop yields;
5. Multi-date maps of crop types to monitor patterns related to crop change;
6. Knowledge of crop types to monitor condition and improve prediction of crop yield;

7. More precise models of crop types and conditions to improve agricultural economic forecasts;
8. Prediction of biomass for estimating vegetation production, soil protection from erosion forces, nonpoint source pollution, wildlife habitat quality and other related factors;
9. Crop type and condition information to more accurately predict production of biogeochemicals such as CO₂, CH₄, and other greenhouse gases that are inputs to global climate models;
10. Provide information regarding limiting factors (i.e., economic constraints of pumping, fertilizing, etc.) used in conjunction with other factors, such as changes in climate for predicting changes in rural LULC;
11. Accurate prediction of rural LULC used to assess the effectiveness of government programs such as the U.S. Soil Conservation Service (SCS) Conservation Reserve Program; and
12. Prediction of water demand based on rural LULC that can be related to rates of draw-down of underground water supplies.

Statement of Objectives:

The objectives of the first phase of this study were to:

1. Determine whether the use of multitemporal remotely sensed imagery, as opposed to the typical single-date imagery, would enhance our ability to model rural land use/land cover (LULC) in the High Plains Region.
2. Determine how annual and seasonal variations in precipitation and temperature patterns might influence our ability to model and monitor rural LULC.
3. Determine whether spectral classification results can be enhanced by integration of soils, climatic, and other environmental factors.
4. Develop a remote sensing applications outreach program for local, state, and federal government, and K-12.

Assessments of change in groundwater availability, understanding the impact of the Conservation Reserve Program (CRP), and analyzing reversion of lands to shortgrass prairie in the High Plains region are often limited by inadequate spatial and temporal information. Until we accomplished the first objectives of this study, no economically feasible and repeatable method was available for accurately mapping rural LULC. Once we had developed an accurate method, the objectives of the second phase of this project were to:

5. Determine the potential implications of lower water availability to agricultural economic systems, both in terms of diminishing groundwater availability and less precipitation due to changing climate patterns.
6. Examine some potential economic impacts on Kansas farmers of changes in the 1995 U.S. Farm Bill.
7. Determine the relationship between multitemporal spectral response patterns and land use patterns that influence biophysical and compositional characteristics of natural vegetation throughout Kansas.

8. Continue our remote sensing applications outreach program for local, state, and federal government, and K-12.

PROJECT WORK LOCATION:

(Geographic location where the work is actually being performed)

The research was conducted in Finney County, Kansas and the technology transfer activities were conducted throughout the state. The research was conducted at the Kansas Applied Remote Sensing Program Laboratory at the University of Kansas (KU), and the Geography Department at Kansas State University (KSU). Most of the image processing was performed by personnel at KARS, and the GIS database development and analytical operations, and K-12 educational components were conducted at KSU in the Geography Department.

KEY WORDS:

(Key words that best describe the project)

remote sensing, multitemporal, land use/land cover, image classification, technology transfer, applications

INPUT:

(All the inputs that are needed to complete and carry out the project. Human and physical capital and raw materials required for the research and applications process. It describes the cost of doing business and includes: budget, number of researchers/teams, data required, use of other assets e.g., aircraft, ancillary data.)

The NASA funding for personnel, equipment, travel, and other miscellaneous expenses was \$200,000 in 1994 and \$100,000 in 1995. In addition, NASA purchased 20 (10 each year) Landsat TM satellite images at an estimated value of \$88,000.

These funds were used to partially support 2 professors, 5 graduate students, and 2 undergraduate students. The personnel were working in two teams, 4 at the University of Kansas (Kansas Applied Remote Sensing (KARS) Program, and 3 at Kansas State University (Geography Department). A total of 6 months of summer salary was covered for the professors and the students were employed 50% time for 9 months (school year) and 100% time for 3 months (summers).

Other data that was acquired at no cost for this project included:

1. a) digital soils maps, b) farm records of crop types and Conservation Reserve Program lands (U.S. Natural Resource Conservation Service (NRCS) and U.S. Farm Service Agency (FSA) in Garden City, Kansas.
2. Digital maps for Finney County, Kansas: a) hydrology, b) water table depth, c) depth of the Ogallala Aquifer. (Kansas Geological Survey)

OUTPUT:

(Immediate observable products of the research and applications activity. Describes the efficiency resulting from the use of the resources. Includes data sets obtained, models developed, papers published, number of presentations made, number of graduate students supported, dissertations written, etc.,)

Models

- A multitemporal classification model was developed that improved classification accuracy of grasslands and crop lands from 55-60% to 97-100% accuracy as verified from hundreds of ground control sites.
- Post classification change detection approach that allowed us to model the spatial distribution of Conservation Reserve Program lands with better than 90% accuracy
- A GIS analytical approach for performing areal correspondence analysis for determining the relationship between CRP land locations and soil properties.
- A technology transfer model for K-12 public education

Model Output (Maps)

- Classification maps for Finney County for 1987, 1989, 1992 with the following land cover types: 1) cropland 2) grasslands, 3) urban. The overall map accuracy was 97% for all three years.
- Classification maps for Finney County for 1987, 1989, 1992 with the following land cover types: 1) grasslands, 2) urban, 3) winter wheat, 4) milo, 5) corn, 6) alfalfa, 7) fallow, 8) water bodies. The overall accuracy was 91%.
- A map of the location of Conservation Reserve Program lands generated from Landsat imagery with over 90% accuracy.
- A map of grasslands and riparian vegetation for 1992 with the following classes: 1) riparian, 2) shortgrass prairie, 3) sand sage prairie, 4) water bodies. Accuracy is still being evaluated under the U.S. GAP Program.

Publications, Proceeding Papers, Abstracts, and Reports

- Egbert, S. L., R. Lee, K. P. Price, and M.D. Nellis. Mapping Conservation Reserve Program (CRP) Lands using multi-seasonal Thematic Mapper imagery. *(In Review, submitted to Geocarto International)*.
- Price, K. P., S. L. Egbert, M.D. Nellis, and R. Lee. Developing a land cover modelling protocol for the High Plains using multi-seasonal Thematic Mapper imagery. *(In review, Transactions of the Kansas Academy of Science, Invited paper..)*
- J. Wu, M.D. Nellis, M.D. Ransom, K.P. Price, and S.L. Egbert. Evaluating CRP Land Soil Properties by Using Remote Sensing and GIS Techniques. *Journal of Soil And Water Conservation* (accepted, forthcoming 1997).
- M.D. Nellis and K. Price. 1996. Sustainability of Rural Land Use Systems in Western Kansas: Myth or Reality. *Proceedings of The IGC Rural Sustainability Study Group*, accepted, forthcoming, The Hague: IGC
- M.D. Nellis, B. Rundquist, and K. Price. 1996. Groundwater Level Declines in

- Southwest Kansas," *Geographic Insights*, Vol. 6, No.2 (May, 1996), pp. 12-14.
- M.D. Nellis, K. Price, S. Egbert and J. Wu. Natural Resource Capability of CRP Lands as Grasslands in Southwest Kansas - A Remote Sensing and GIS Perspective. *Geocarto International* (accepted, forthcoming, 1996).
- Rundquist, B., M. D. Nellis, and K. Price. 1996. Groundwater level declines in Southwestern Kansas. *Geographic Insights*, Vol. VI(2):12-14.
- Nellis, M.D., K.P. Price, and R. Lissitschenko. 1995. An analysis of rural land use in the Kansas High Plains using Landsat Imagery. *Geographic Insights*, 1(2):14-17.
- Price, K. P., S. L. Egbert, M.D. Nellis, and R. Lee. Developing a land cover modelling protocol for the High Plains using multi-seasonal Thematic Mapper imagery. (*In preparation, to be submitted to International Journal of Remote Sensing*).
- M. D. Nellis, J. Wu, M. Ransom, K. P. Price, S. L. Egbert. Evaluating Conservation Reserve Program Land in Southwest Kansas using remote sensing and GIS techniques. (*Invited paper for Special Issue of Geocarto International*).
- Egbert, S.L., K. P. Price, M.D. Nellis, and R. Lee. 1995. Developing a land cover modelling protocol for the High Plains using multi-seasonal Thematic Mapper imagery. *ACSM/ASPRS '95 Annual Convention and Exposition*, Charlotte, North Carolina, February 27-March 2. pp. 836-845
- Price, K.P. M.D. Nellis, S.L. Egbert, and R. Lee. 1995. Modelling High Plains land cover using multi-date Thematic Mapper imagery. *91st Annual Meeting of the Association of American Geographers (AAG)*. Chicago, IL. March 14-18. (Published Abstract)
- Price, K. P. and M. D. Nellis. 1994. Development of a land use mapping and monitoring protocol for the High Plains Region: A multitemporal remote sensing application. *Progress Report, NASA Headquarters, Mission to Planet Earth*. Washington, DC. December, 1994. 36pp.

Professional Papers Presented

- Price, K.P. S. L. Egbert, M. Duane Nellis, and R. Lee. 1996. Developing a land cover modelling procedure for the high plains using multi-date thematic mapper imagery. *128th Annual Meeting of the Kansas Academy of Sciences*, Emporia State University, March 21-22, 1996. (*Invited paper*).
- J. Wu, M. Ransom, M.D. Nellis, and K. Price. 1996. Analyzing Soils and Land Use Relationships, by Remote Sensing and GIS," *American Society of Agronomy*, November 1996, Indianapolis, Indiana.
- M.D. Nellis and K. Price. 1996. The Sustainability of Rural Land Use Systems in Western Kansas: Myth or Reality," *28th International Geographical Congress*, August 1996, The Hague, The Netherlands.
- M.D. Nellis, K. Price, J. Wu, and S. Egbert. 1996. Natural Resource Capability of CRP Lands as Grasslands in Southwest Kansas: A Remote Sensing and GIS Perspective. *Society of Range Management National Meeting*, (invited) GIS/Remote Sensing Symposium, February 1996, Wichita, KS.
- Price, K.P. M.D. Nellis, S.L. Egbert, and R. Lee. 1995. Modelling High Plains land cover using multi-date Thematic Mapper imagery. *91st Annual Meeting of the Association of American Geographers (AAG)*. Chicago, IL. March 14-18.
- M. D. Nellis, J. Wu., M. Ransom, K. P. Price, and S. L. Egbert. 1995. Evaluating Conservation Reserve Program Land in Southwest Kansas using remote sensing and GIS techniques.

Great plains-Rocky Mountain AAG, Rapid City, South Dakota.
M. D. Nellis, J. Wu, M. Ransom, K. P. Price, and S. L. Egbert. 1995. Evaluating Conservation Reserve Program Land in Southwest Kansas using remote sensing and GIS techniques. *Agronomy Society of America*, St. Louis, Missouri.

Outreach Results

- The following publication was distributed to over 2,500 K-12 school teachers in Kansas. This publication has color Infrared Landsat Imagery and a lesson plan that teachers can use to introduce students to remote sensing.

Nellis, M.D., K.P. Price, and R. Lissitschenko. 1995. An analysis of rural land use in the Kansas High Plains using Landsat Imagery. *Geographic Insights*, 1(2):14-17.

- Approximately 90 K-12 teachers were given intensive workshop instruction on the use of Landsat thematic mapper data for mapping rural land use in Southwest Kansas as part of summer institutes in 1994, 1995, and 1996.
- Approximately 40 teachers participated in two intensive workshops in southwest Kansas that focused on rural land use systems of this Kansas region. As part of this intensive workshop, teachers were taught how satellite remotely sensed imagery can be use for resource mapping and monitoring.

OUTCOME:

Long term consequences of the program

- We have developed a classification approach that allows us to accurately classify land cover types at over 90% accuracy at the Anderson Level IV (Crop type and plant community levels). Previous to this work, we could not accurately classify major cover types in Kansas even at the Anderson Level I (agricultural lands, grasslands). These findings will also work in other parts of the Great Plains and will have lasting consequences for many years.
- A commercial company has been developed through a small business development program at the University of Kansas. The company name is *Ecosystem Testing Designs Inc. (ETDI)*. This means more jobs in the region, increased state revenue, increased technology transfer, and development of new remote sensing products. This company is now marketing products that were developed as a result of the Finney County NASA project. The products include:
 - 1) The GreenReport which is now being marketed to ~150,000 potential subscribers,
 - 2) sea surface temperature and phytoplankton maps (daily product) to begin distribution October 25, 1996,
 - 3) forest moisture and temperature maps with lightning strikes and fire monitoring maps (daily product). To begin distribution October 25, 1996

Products now being developed include: corn and winter wheat yield maps which will be used by the insurance industry for crop insurance purposes, and by the commodities market. The U.S. Department of Agriculture will now be able to more accurately map crop types using satellite imagery as apposed to flying aerial photography and manually interpreting the land cover types. This will save much time and taxpayer dollars. It will also improve classification accuracy.

- More K-12 school teachers are now introducing students to remote sensing technologies. These students will also know that NASA is the developer of these technologies.
- Kansas is leading the nation as the first state to use a multitemporal (3 dates) classification approach for mapping vegetation types at the UNESCO Alliance level (There are 42 vegetation alliances in Kansas that we are now attempting to map as part of the National Biological Service GAP program. The results of this project will be the first highly detailed vegetation map ever produced for Kansas. This map will be used by many federal, state, and local agencies for many different purposes (i.e., wildlife management, hydrologic modeling, and land use planning).

Grants Resulting from the Project

- M. D. Nellis, K. P. Price, J. S. Aber, C. Allen, S. P. Gogineni, J. Briggs, D. Goodlin, J. Harrington, G. Henebry.** Spatial and spectral scale dimensions for modeling Kansas rural resource systems: projections for global change. NASA EPSCoR Program. \$590,118. (10/96 - 10/99).
- Price, K.P. and E.A. Martinko.** 1996. Development of a land cover map at the vegetation alliance level for the State of Kansas. U.S. Environmental Protection Agency, Region 7. \$90,000. (10/1/96 - 9/31/98).
- Price, K.P. and E.A. Martinko.** 1996. Kansas land cover GIS database update. State GIS Policy Board, Kansas Department of Water Resources. \$55,959. (7/1/97 - 6/31/98) (with probable funding for two additional years).
- Cully, J.F., G.A. Kaufman, E.A. Martinko, and K.P. Price.** 1996. GAP Analysis in Kansas 1996-1999. Kansas Department of Wildlife and Parks. \$135,000. (11/1/96 - 10/31/99).
- Martinko, E.A. and K.P. Price.** 1996. Land cover classification for the Kansas GAP analysis project. National Biological Service. \$93,020. (10/9/96 - 10/8/99).
- Lauver, C. and K.P. Price.** 1995. Land cover classification for the Kansas GAP analysis project. National Biological Service. \$54,046. (10/9/95 - 10/8/96).
- Price, K. P. and E. A. Martinko.** 1995. An inventory of Lessor Prairie Chicken Habitat in Southwestern Kansas -- A satellite remote sensing and GIS approach to rangeland classification. Kansas Department of Wildlife and Parks, \$9,260. (6/25/95 - 10/1/97).
- Price, K. P.** 1994. Analysis of wheat stubble management in western Kansas: A Landsat remote sensing application. (6/94-9/94), \$3,400.
- Price, K. P., E. A. Martinko, F. J. deNoyelles, S. D. Campbell, C. Becker, R. Youngquist, F. Miller, and R. Zulu.** 1995. Developing a natural resource inventory and monitoring program for the Zambian Government: A satellite remote sensing and geographic information systems applications and technology transfer program. \$22,000,000 Zambian Government and USAID (6/1996-6/1999). (In review).

Martinko, E. A. and K. P. Price. 1996. Mapping irrigated agriculture in Rawlins County, Kansas and Red Willow County, Nebraska — A pilot study using a multivariate Landsat image classification approach. Kansas Department of Agriculture, Division of Water Resources. \$94,814 (12/1/95-8/15/96).

Martinko, E. A., K. P. Price., and S. L. Egbert. Mapping irrigated agriculture in Rawlins County, Kansas and Red Willow County, Nebraska — A pilot study using a multivariate Landsat image classification approach. (Continuation) Kansas Department of Agriculture, Division of Water Resources. \$250,000 (12/1/96-12/1/98).

IMPACT:

(Total consequences of the program, including intended benefits and unintended positive results. Includes description of utility and benefit to the customers. Why was it useful? How was it useful? How was it used in its end use in decision-making or could be use in the future? Most important of all –it answers the question: "So what?" Includes things such as new knowledge shared, cost saved, new application done that were not possible before. How did or would the results impact the public good or expanded commercialization?)

- A new remote sensing value added company has been developed that is already exploring international markets and will bring additional funds into the United States resulting in many economic benefits. New jobs are already being created.
- Through the distribution of our products, many taxpayers are being introduced to the benefits of remote sensing. The Chicago Board of Trade is already investigating the use of our GreenReport for a variety of purposes such as determining the health of U.S. crops and establishing crop prices.
- The U.S. Forest Service will save property, resources, time, and lives as we provide them with timely maps showing forest fire locations and helping them predict the potential for forest fires.
- The fishing industry will save valuable time and money as they are able to use the products from ETDI to plan day-to-day fishing activities.
- The State of Kansas is now using the technology to determine how surrounding states are using valuable irrigation waters. The information is helping them decide whether to challenge surrounding states for not abiding by legal agreements concerning water consumption. At this time, attorneys in Kansas are deciding whether to enter into Supreme Court litigation with a neighboring state for overusing water on a major river system. The maps that we can now produce because of NASA earlier support allow us to classify 10 crop types at 91% accuracy, and determine whether the crop is irrigated. The information we can now provide our Attorney General's Office is being used as a key factor in deciding whether to enter into a court battle over water.